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COVERAGE BY THE MANNED SPACE FLIGHT NETWORK BETWEEN THE NEAR-EARTH AND DEEP-SPACE PHASES OF THE APOLLO LUNAR MISSION

October 1, 1964

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P. F. Sennewald

Work Performed for Manned Space Flight, National Aeronautics and Space Administration as part of Task 15 under Contract NASw-417.

BELLCOMM, INC. October 1, 1964

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1.0 Summary

In the Apollo lunar landing mission profile, there are two phases, post-injection and pre-reentry, where a transition is made between near-earth and deep-space operations. This report presents the results of a study of the communications and tracking coverage afforded by the Manned Space Flight Network (MSFN) during these two periods. Specific improvements are recommended in the system sensitivity of the MSFN stations planned for Carnarvon and Ascension to eliminate a coverage gap in the post-injection coverage; the pre-reentry coverage provided by the MSFN appears to be satisfactory for landings at Samoa and Hawaii.

A preliminary study* on this subject has been reviewed with representatives of the Manned Spacecraft Center (Flight Operations Division), the Goddard Space Flight Center and the Office of Tracking and Data Acquisition. Many of the results and comments from these reviews have been incorporated into this report.

2.0 Recommendations and Conclusions

An increased system sensitivity is recommended for the Unified S-Band (USB) System stations planned for Carnarvon and Ascension. This is necessary to satisfy the minimum operational communications requirement of telemetry at 1.6 KBS and two-way voice communications** throughout the CSM/LEM transposition phase, i.e., from 20 to 60 minutes after injection. This recommendation can be implemented with cooled parametric amplifiers at these stations. The resulting improvement will also provide telemetry reception at 51.2 KBS until approximately 40 minutes after injection. If telemetry at 51.2 KBS is required throughout transposition, an increase in the size of the USB System ground antenna is required. This could be implemented by relocating the MSFN deep-space stations and associated 85 foot antennas from Madrid and Canberra (where they are collocated with the DSIF deep-space stations) to Ascension and Carnarvon.

Improvements in the MSFN coverage of the pre-reentry phase are not recommended as the coverage appears to be adequate. Two-way voice communications and telemetry at 1.6 KBS is provided by the MSFN during the pre-reentry phase if the SM (and

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*Reference 9.

**A range tracking capability is also available with a reduction in maximum range of about ten percent.

the high-gain antenna) is staged within the last 30 minutes before reentry as currently planned. Telemetry at 51.2 KBS is limited on some trajectories to the last 20 minutes before reentry by the range capability of the USB System station at Carnarvon. Therefore, an increase in the USB System capability at Carnarvon would increase the pre-reentry coverage for telemetry at 51.2 KBS. In addition, any increased capability at Carnarvon would provide coverage which is not now available if the CSM high-gain antenna is not functioning prior to SM staging.

3.0 Station Locations Considered

The station locations considered in this study are taken from those currently planned for the MSFN as shown in Table 3-1. The implementation planned for these stations includes the Unified S-Band (USB) System which is being provided for Apollo support. Three MSFN deep-space stations are to be collocated with the three DSIF deep-space stations, which will serve as hot, on-line backups during Apollo missions. Each of the six deep-space stations will have an 85-foot diameter antenna. The deep-space stations (DSIF and MSFN) are planned to be implemented for dual frequency operation to permit simultaneous communications and tracking support of the CSM and LEM. The nine near-earth sites will be implemented with 30-foot diameter antennas. Five of these will also have the dual frequency capability.

Table 3-1

LAND STATIONS CURRENTLY PLANNED FOR APOLLO SUPPORT

* Dual Frequency

Deep-Space Stations with 85-Foot Antennas

MSFN	DSIF (Hot, On-Line Alternates)
*Goldstone	*Goldstone
*Madrid	*Madrid
*Canberra	*Canberra

Near-Earth Stations with 30-Foot Antennas

*Cape Kennedy	*Ascension	*Hawaii
Bermuda	*Carnarvon	Guaymas
Antigua	*Guam	Corpus Christi

4.0 Post-Injection Phase

The most critical period during the post-injection phase for MSFN communications and tracking coverage occurs during the CSM/LEM transposition. During transposition, the LEM is repositioned and connected to the CSM to permit crew access. Prior to completion of transposition, the CSM high-gain S-band antenna is not available for use as it is enclosed in its stowed position adjacent to the SM propulsion nozzle by the adapter panels. Therefore, the performance of the USB System during transposition is dependent upon the use of the CSM omni-directional antenna which has a gain on the order of -3db.

Under current operational planning, transposition will start at 20 minutes after injection and will require a maximum of 40 minutes for completion. Thus, deployment of the high-gain antenna will not be assured until 60 minutes after injection.*

The coverage capability of the MSFN is determined by the above-horizon visibility of each station taken together with the range limitations imposed by the USB System when operating with the omni-antenna. Figure 4-1 shows a minimum combination of MSFN stations, including the planned deep-space stations, which provide the required visibility of all permissible injection trajectories** at 20 minutes after injection. The visibility of an injection ship located near South Africa is not shown but would fill the gap shown in Figure 4-1. Figures 4-2 through 4-6 show the increased visibility due to the increased altitude at several points during and after the transposition phase.

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*Even if the antenna is physically capable of deployment before the end of transposition, it is not clear that it will have an automatic earth pointing capability at the relatively low altitudes which are encountered during transposition. Manual pointing of the antenna by the astronauts is not considered feasible because of the anticipated crew work load during this phase.

**Based on a launch azimuth range of 72° to 108° and injection occurring between 45 minutes (or half an orbit) and 270 minutes (three orbits) after launch.

Considering that the visibility of the deep-space stations with the larger antennas is more desirable, the additional visibility contributions of Antigua, a ship near South Africa, Hawaii, and Guam are reduced gradually to zero with increasing time and altitude in the order listed. Those stations providing redundant visibility as the altitude increases have been deleted from succeeding figures. However, Carnarvon and Ascension contribute significantly to the visibility at the end of transposition as shown in Figure 4-5. Alternatively, the visibility of an injection ship near South Africa, but in the Atlantic Ocean, could be used to fill in the region not covered by the deep-space stations at 60 minutes after injection. This is shown in Figure 4-7.

Therefore, depending upon the range limitations associated with the 30 foot ground antennas, coverage gaps may occur during transposition in areas which are visible only from Carnarvon and Ascension or a ship near South Africa.

4.1 USB System Range Limitations and Possible Improvements

The basic functions of the USB System include updata to the CSM, two-way duplex voice communications with both spacecraft, telemetry from both spacecraft, and tracking of both spacecraft. Tracking involves transmission to and from the spacecraft. In the current design,* the maximum range is determined by the spacecraft-to-MSFN link. Specifically, whenever voice and telemetry are transmitted from the CSM, the maximum range is determined by:

a. The telemetry subcarrier power level if the telemetry rate = 51.2 KBS, or

b. The voice subcarrier power level if the telemetry rate = 1.6 KBS.

Therefore, the conventional range equation, with an additional factor to adjust for the modulation loss due to the power division among the USB System carrier and subcarriers, can be used to calculate performance in the conventional manner.

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*The USB System design considered in this memorandum is based primarily on information contained in Reference 1. References 2 and 3 also provide information on CSM transmission losses, antenna gains, and modulation losses. Since Reference 1 is the basic procurement document for the ground portion of the USB System it is used as the primary reference to establish realistic estimates of system performance.

This has been done in Table 4-1 for the current design of the USB System as defined in References 1, 2, and 3. An examination of this range equation will show that all of the components except CSM transmission losses and CSM omni-antenna gain are either constant or well-defined in terms of the design parameters of the USB System.

The CSM antenna gain is an unknown, as the Block II, survivable, S-band omni-antennas for the CSM have not been designed. An estimated gain of -3db appears to be a reasonable expected value to realize from two switchable pairs of cavity antennas. A CSM transmission loss of 5.5db includes 4.0db which is representative of current CSM losses.* An additional 1.5db allowance has been included for the losses which will probably be incurred (circulator, etc.) when the design change is implemented to provide simultaneous phase modulated and frequency modulated carriers from the CSM. In any event, the effect of variations in the losses and other system parameters will be considered below.

The ranges calculated in Table 4-1 for the CSM-to-MSFN link using the currently planned USB System are shown as Case A in Figures 4-8 and 4-9 where range performance is related to elapsed time after injection during the transposition phase. Also illustrated is the effect of a ±2.0db variation in USB System performance (e.g., variation in losses, antenna gains).

Cases B and C represent the improvements in USB System performance which are realized with the use of a cooled parametric amplifier; liquid nitrogen in Case B for a 2.38db improvement, and liquid helium in Case C for a 3.89db improvement. Case D represents the improvement over Case A realized by increasing ground antenna diameter from 30 feet to 85 feet, an increase in gain of 8.8db. The bases of the improvements in Cases B and C are illustrated in Figure 4-12, where the improvement possible in USB System temperature is shown as a function of receiver temperature. The improvement in Case D of 8.8db is based on the 52.8db gain of an 85-foot antenna as given in Reference 4 at S-band.

Consideration is currently being given to providing telemetry support of the S-IVB/IU during the post-injection phase. Table 4-2 illustrates the performance calculation of an S-band PCM FM telemetry system that would provide telemetry transmission at 72 KBS from an omni-antenna on the S-IVB/IU. The basic parameters such as losses, transmitter power, antenna

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*See References 2 and 3.

gains, etc. are comparable to those of the USB System where appropriate. Figure 4-10 illustrates this performance as Case A, together with the same improvements described earlier, i.e., Cases B, C, and D. The improvement in Case D can also be realized with an equivalent increase in the S-IVB/IU antenna gain, i.e., from a gain of -3.0db to +5.8db for a total increase of 8.8db.

Recently a study has been initiated by Marshall Space Flight Center to establish the feasibility of using the USB System on the S-IVB/IU. Table 4-1 also includes a determination of the range capability of the USB System modified to support the S-IVB/IU. It is basically the same system used on the CSM without the voice subcarrier and with the telemetry subcarrier modulation index optimized for minimum modulation loss.

These capabilities are shown in Figure 4-11, together with the improvements afforded by the changes of Cases B, C, and D.

4.2 USB Capabilities and Operational Requirements

A selection of one of the methods of improving USB System performance for Carnarvon and Ascension will depend, in part, upon the operational requirements imposed during the post-injection phase. The following table shows the USB System functional capabilities realized for the transposition phase for Cases A, B, C, and D.

Table 4-3

USB System Capabilities Throughout Transposition

Case	Ranging, Voice, Updata, and:	
	Telemetry at 1.6 KBS	Telemetry at 51.2 KBS
A	NO	NO
B	YES	NO
C	YES	NO
D	YES	YES

Mandatory requirements currently exist for voice and telemetry communications with the CSM during transposition. However, the volume of telemetry data required is not completely defined. The Manned Spacecraft Center has stated in Reference 6 that 51.2 KBS is not required for operational data and that 1.6 KBS is sufficient to support operational needs. However, data required for post-mission analysis and biomedical data requirements are not included in these considerations.

Therefore, the deep-space stations supplemented by USB Systems equipped with liquid nitrogen cooled parametric amplifiers at Carnarvon and Ascension will provide ranging, updata, voice, and telemetry at 1.6 KBS throughout the transposition phase.

A small additional increase can be realized with a liquid helium cooled parametric amplifier; however, it is not sufficient to justify the added complexity associated with liquid helium cooling.

A substantial increase in performance can be realized with an increase in antenna size from 30 feet to 85 feet at Carnarvon and Ascension. The impact of providing this capability at these sites will be discussed in paragraph 6.0.

An alternative solution would consist of using a cooled parametric amplifier as part of the USB System of one of the Apollo Instrumentation Ships. The ship would then be located, as shown in Figure 4-7, in the South Atlantic Ocean just off South Africa where it can still provide the coverage required of a ship for tracking after injection.* This would permit a relaxation of the range requirements for Carnarvon and Ascension. In addition, this extended range capability would be available from a mobile station and could be utilized at other locations.

Reception of telemetry on an S-band (or USB) system from the S-IVB/IU during post-injection may require the capability associated with Case D of Figure 4-10. This is dependent upon the length of time after completion of transposition that telemetry is required. Any substantial extension beyond 60 minutes after injection may require the use of 85-foot ground antennas or directional antennas on the S-IVB/IU. The transmission of updata on a USB System to the S-IVB/IU during transposition would not require any increase in range capability over that currently planned for the MSFN. This question of post-injection support of the S-IVB/IU by the MSFN is the subject of a current study at MSFC and should be resolved in the near future.

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*This assumes the use of a second Apollo ship in the Indian Ocean.

Table 4-1

CSM-MSFN and S-IVB/IU-MSFN Unified S-Band System Range Capability

Required $\frac{S}{N}$ Ratio in db = Power Received - Modulation Loss - System Noise (1)

Power Received = $P_r = P_t - L_t + G_t - L_{fs} + G_r - L_p - L_r$ (2)

where

P_t = transmitted power = 20 watts (+13.0 dbw), the maximum CSM power available.

L_t = CSM transmitting losses = 5.5 db, based on current CSM losses and currently planned design changes as described in memorandum.

G_t = CSM omni-antenna gain = -3.0 db, estimated minimum realizable gain.

L_{fs} = free space loss (db) = 20 log R (range in nm) + 20 log f (mcs.) + 37.8; f = 2287.5 mcs.

G_r = ground antenna gain = 44.0* db, minimum ground antenna gain.

L_p = polarization loss = 3.0 db, linear to circular polarization loss.

Modulation Loss = 8.7 db** - CSM telemetry subcarrier, = 12.5 db** - CSM voice subcarrier, = 4.82 db*** - S-IVB/IU telemetry subcarrier.

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*From Reference 1.

**From Reference 2 and assumes simultaneous ranging. The corresponding losses without ranging are approximately 1.0 db less.

***From Reference 5 where a modulation index of m = 1.85 is used to minimize modulation loss for telemetry only transmission.

Table 4-1

System Noise = $KT_s\ B_d$; $k = 1.38 \times 10^{-23}$

B_d = detection bandwidth = 75kc*, PCM FM telemetry @ 51.2 KBS on CSM subcarrier.
= 50kc*, FM voice on CSM subcarrier.
= 110kc, PCM FM telemetry @ 72.0 KBS on S-IVB/IU subcarrier.

$$T_s = \text{system temperature} = \underbrace{\frac{T_{sky}}{L} + \frac{T_{antenna}}{L} + \left(1-\frac{1}{L}\right) T_o}_{= 40^\circ K^*} + \underbrace{(F-1)T_o}_{= 170^\circ K^*};\quad \frac{T_{sky}}{L} = \frac{50^\circ K}{L} \doteq 50^\circ K \text{ for } L \text{ near unity}$$

$T_s = 260^\circ K$

$\left(\frac{S}{N}\right)$ required = 11.5 db* for telemetry subcarrier; = 4.7 db* for voice subcarrier.

Substituting from above into equations (1) and (2) and solving for maximum range:

	Maximum Range	Telemetry Rate	Time After Injection (5° elevation mask)
CSM	6,130 nm	51.2 KBS	26 minutes
	10,650 nm	1.6 KBS	50 minutes
S-IVB/IU	7,440 nm	72.0 KBS	32 minutes

*From Reference 1.

Table 4-2

Range Capability of an Assumed Non-Coherent S-Band Telemetry System for the S-IVB/IU

Modulation Technique		PCM-FM
Frequency		2287.5 mc
Telemetry Rate		72 KBS
S-IVB/IU Telemetry Subsystem		
Transmitter Power		20 watts
Losses		5.5 db
Antenna Gain		-3.0 db
Earth Based Telemetry Receiving Subsystem		
Polarization Loss		3.0 db
System Temperature		260°k
Receiver Temperature	- 170°k*	
Antenna Temperature plus Degradation due to Losses	= 40°k*	
Sky Temperature	= 50°k	
Receiver Loss*		0.25 db
Antenna Gain* (30 foot diameter)		44.0 db
Detection Band Width		275 kc
Doppler Allowance	= 167 kc	
Bit Rate Allowance	= 1.5 x 72 = 108 kc	
Required IF Signal to Noise Ratio		12 db

Range Capability = 8260 nm (maximum slant range at 36 minutes after injection)

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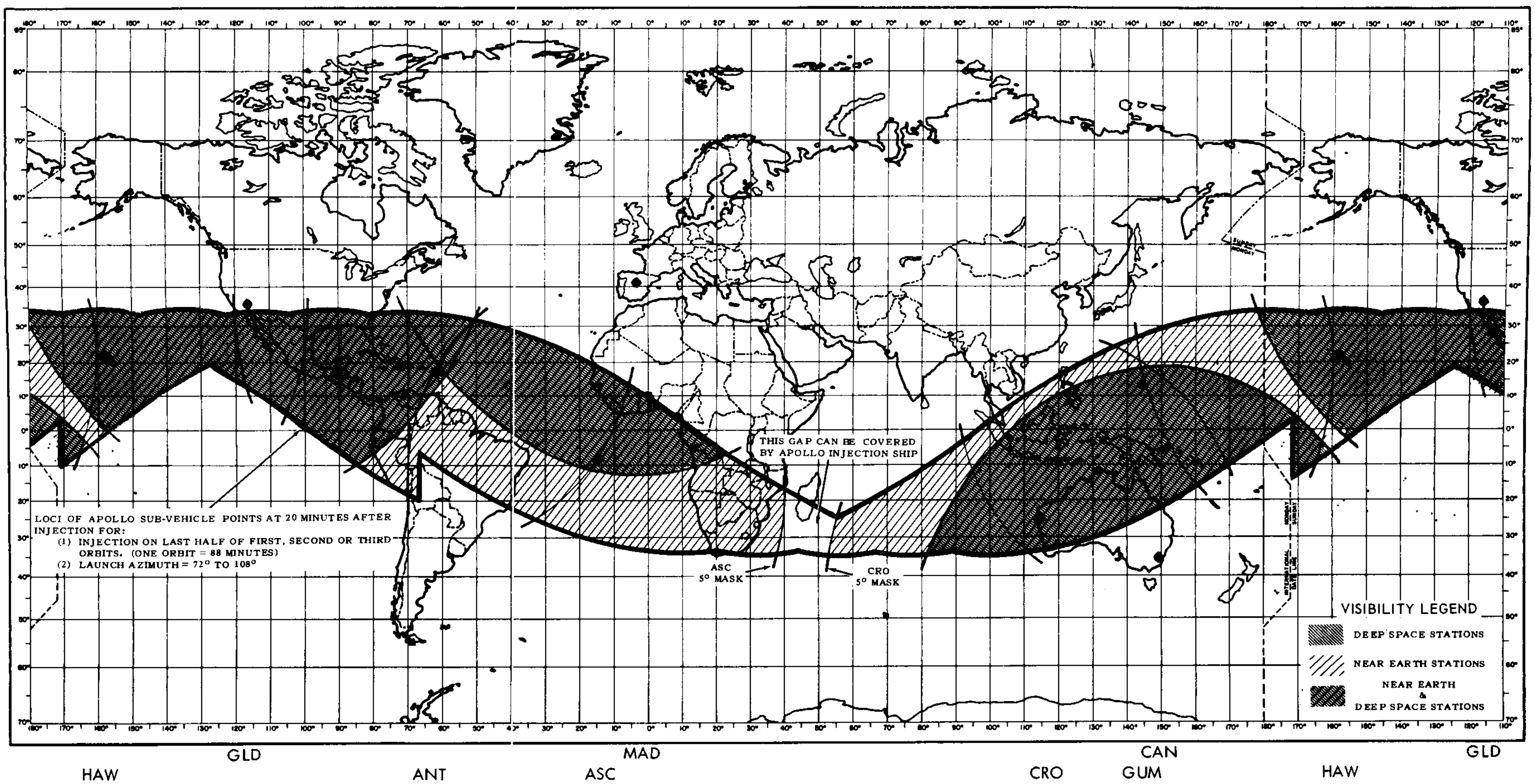
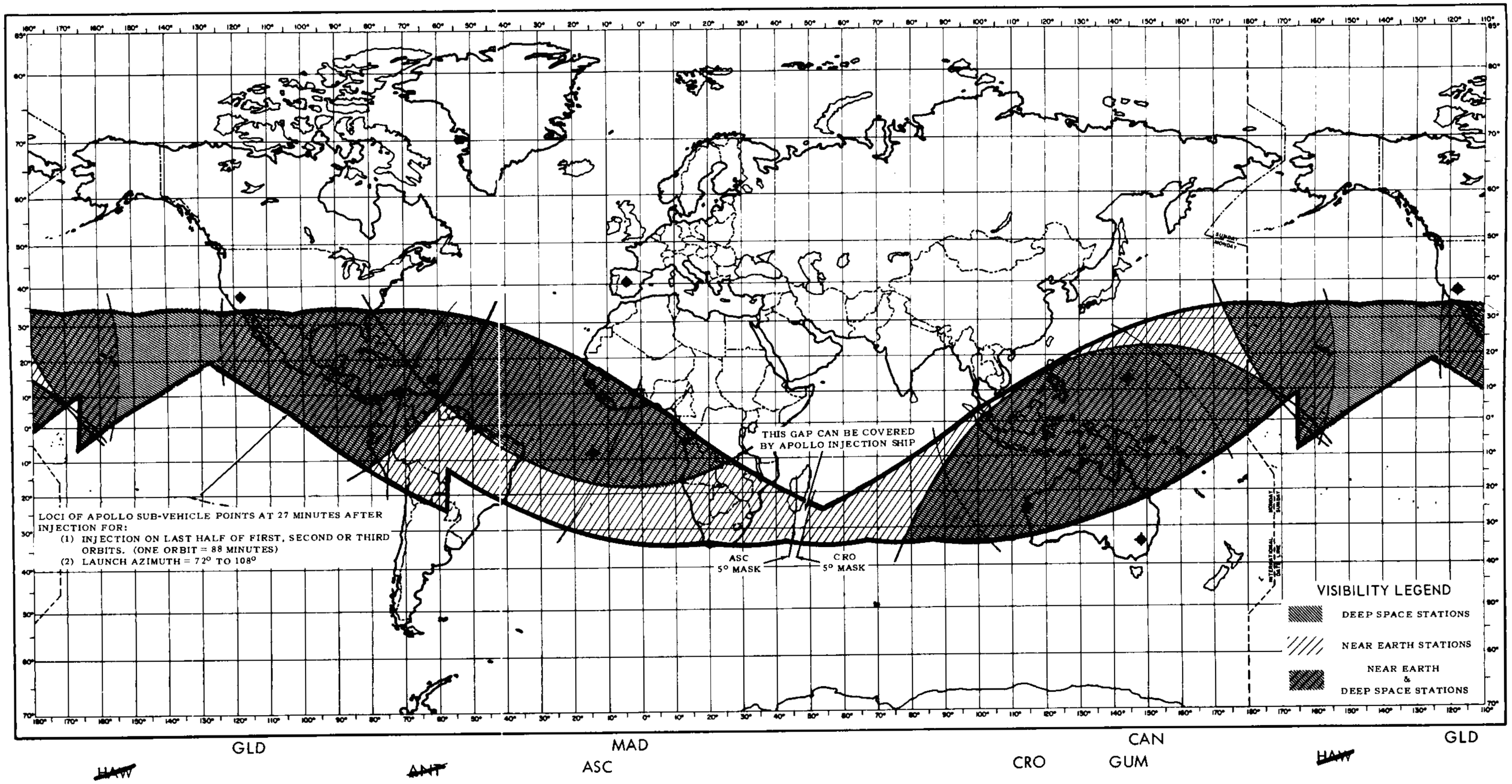
*From Reference 1.



POST INJECTION VISIBILITY - 20 MINUTES AFTER INJECTION
WITH
THREE DEEP SPACE STATIONS
&
A MINIMUM OF NEAR EARTH STATIONS
ALTITUDE = 3000 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 5100 NM

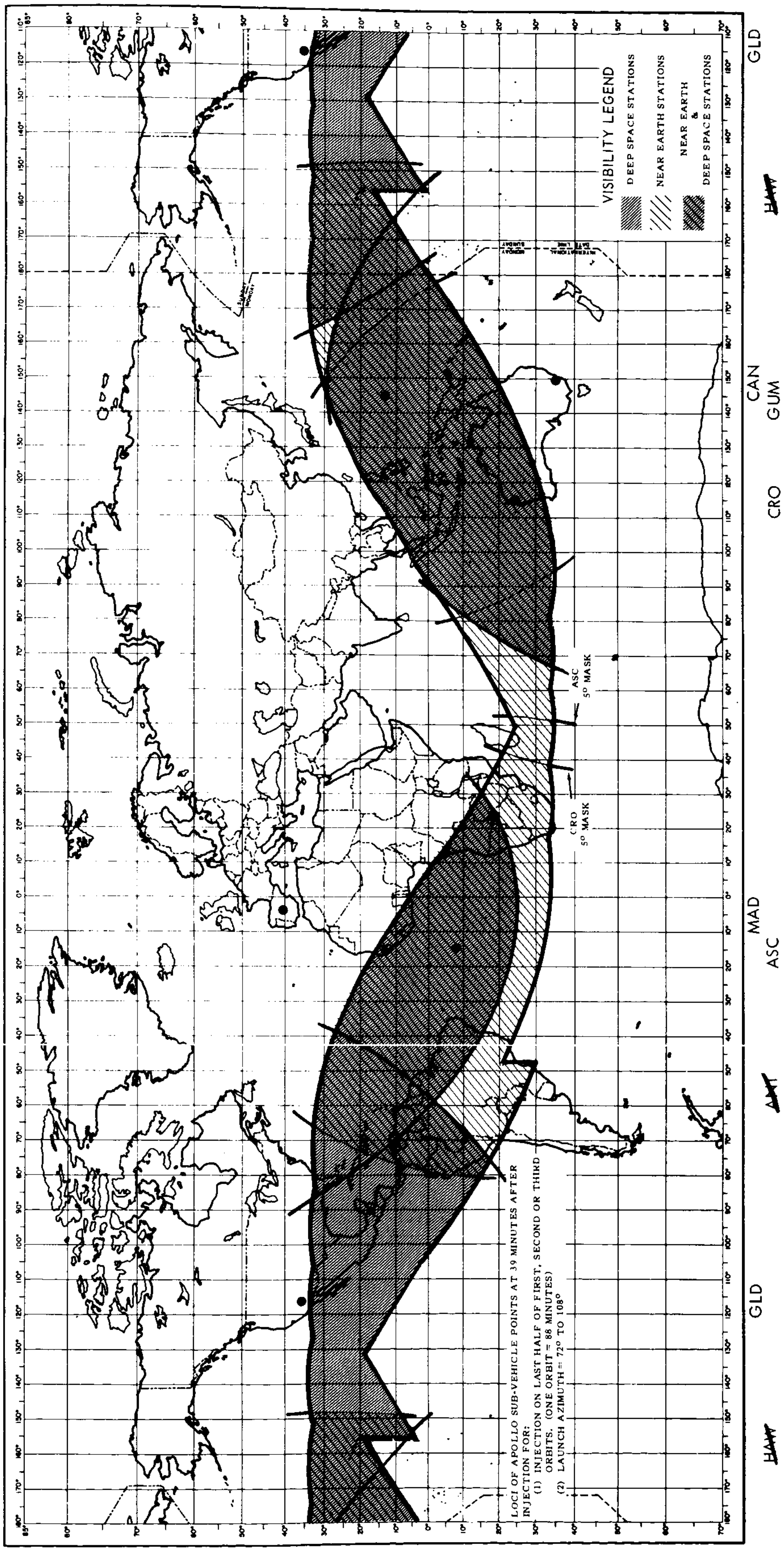
FIGURE 4-1



POST INJECTION VISIBILITY - 27 MINUTES AFTER INJECTION
WITH
THREE DEEP SPACE STATIONS
&
A MINIMUM OF NEAR EARTH STATIONS

ALTITUDE = 4000 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 6300 NM

FIGURE 4-2



POST INJECTION VISIBILITY - 39 MINUTES AFTER INJECTION

WITH

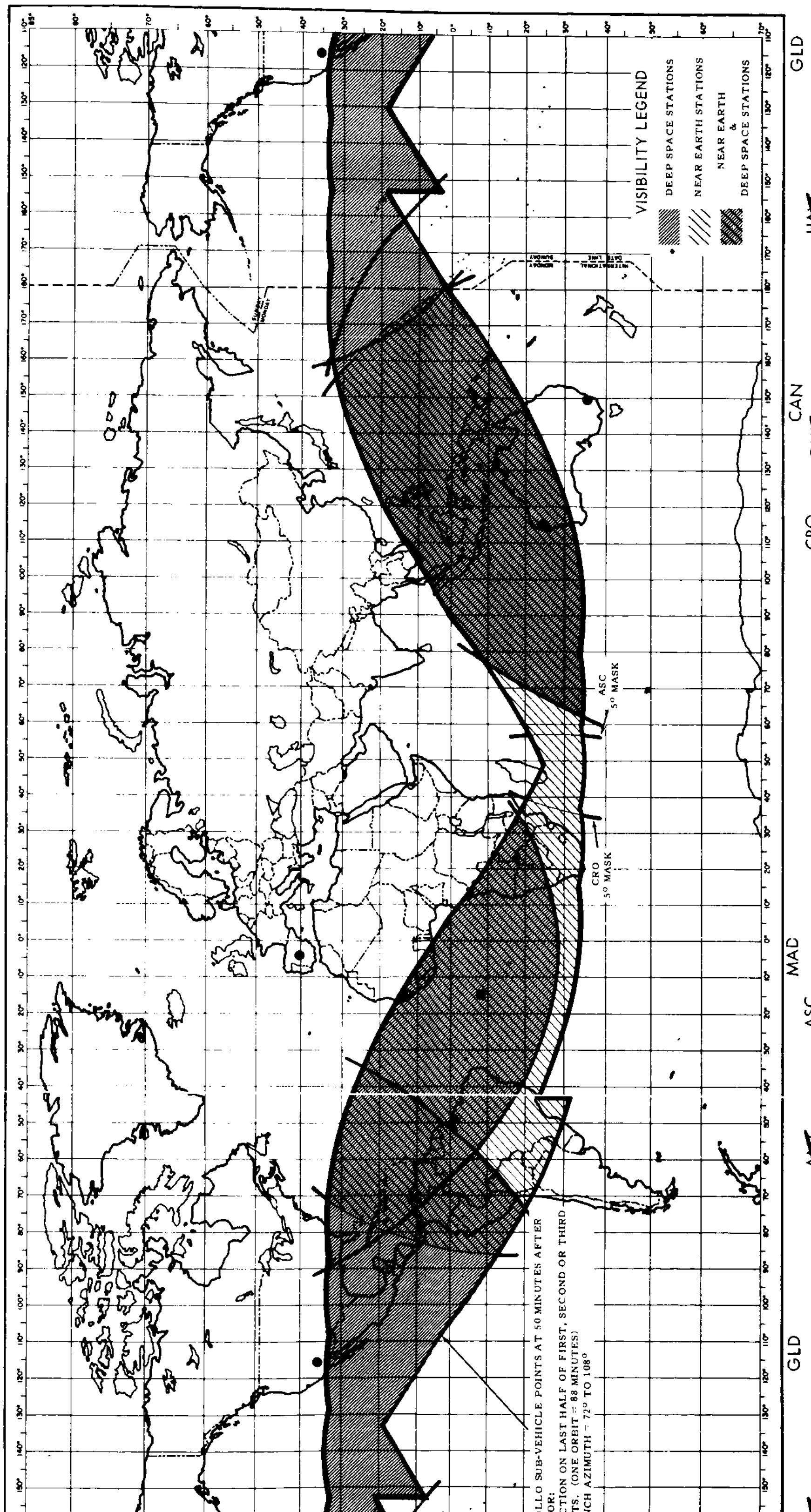
THREE DEEP SPACE STATIONS

&

A MINIMUM OF NEAR EARTH STATIONS

ALTITUDE = 6000 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 8500 NM

FIGURE 4-3



POST INJECTION VISIBILITY - 50 MINUTES AFTER INJECTION

WITH

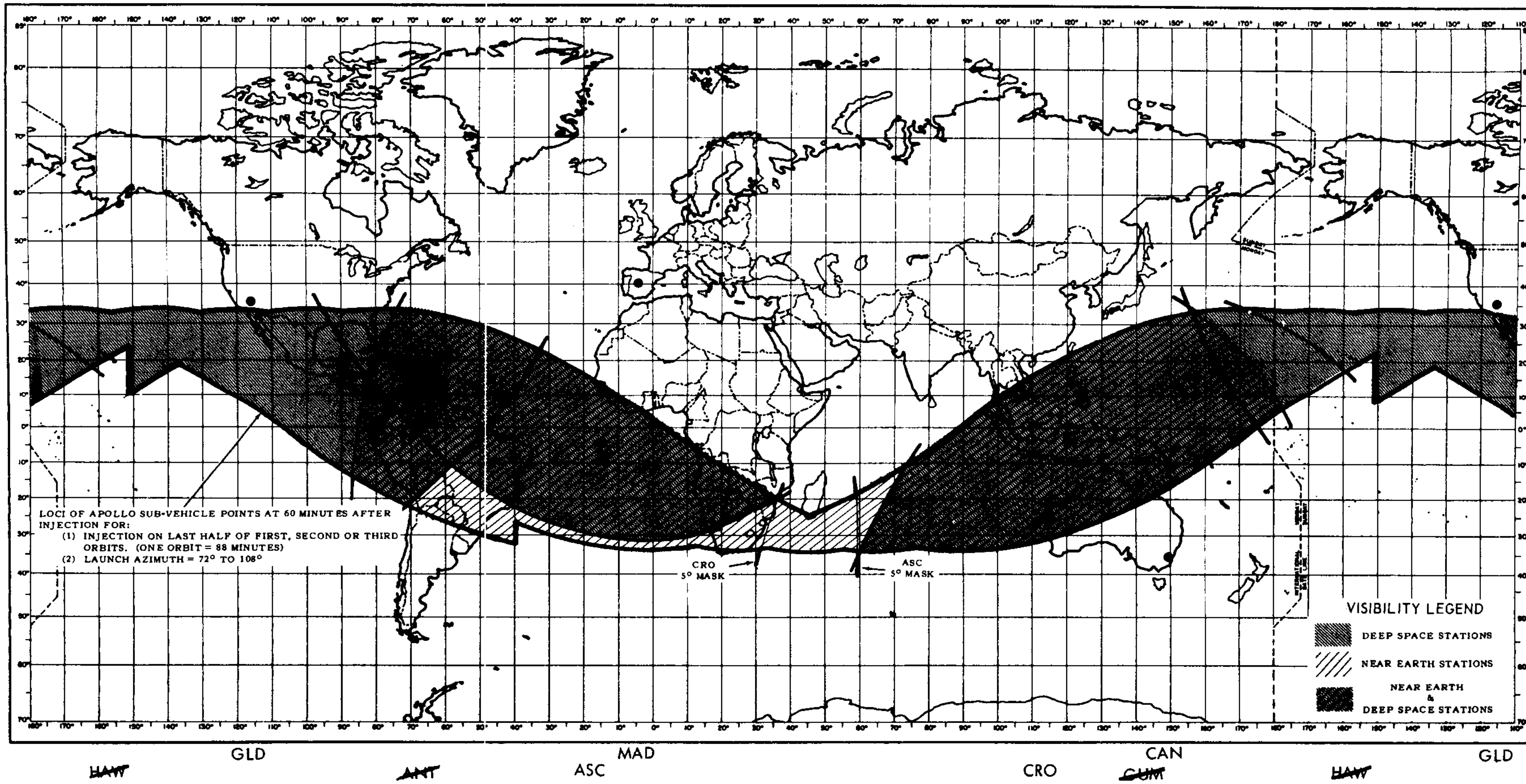
THREE DEEP SPACE STATIONS

&

A MINIMUM OF NEAR EARTH STATIONS

ALTITUDE = 8000 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 10,700 NM

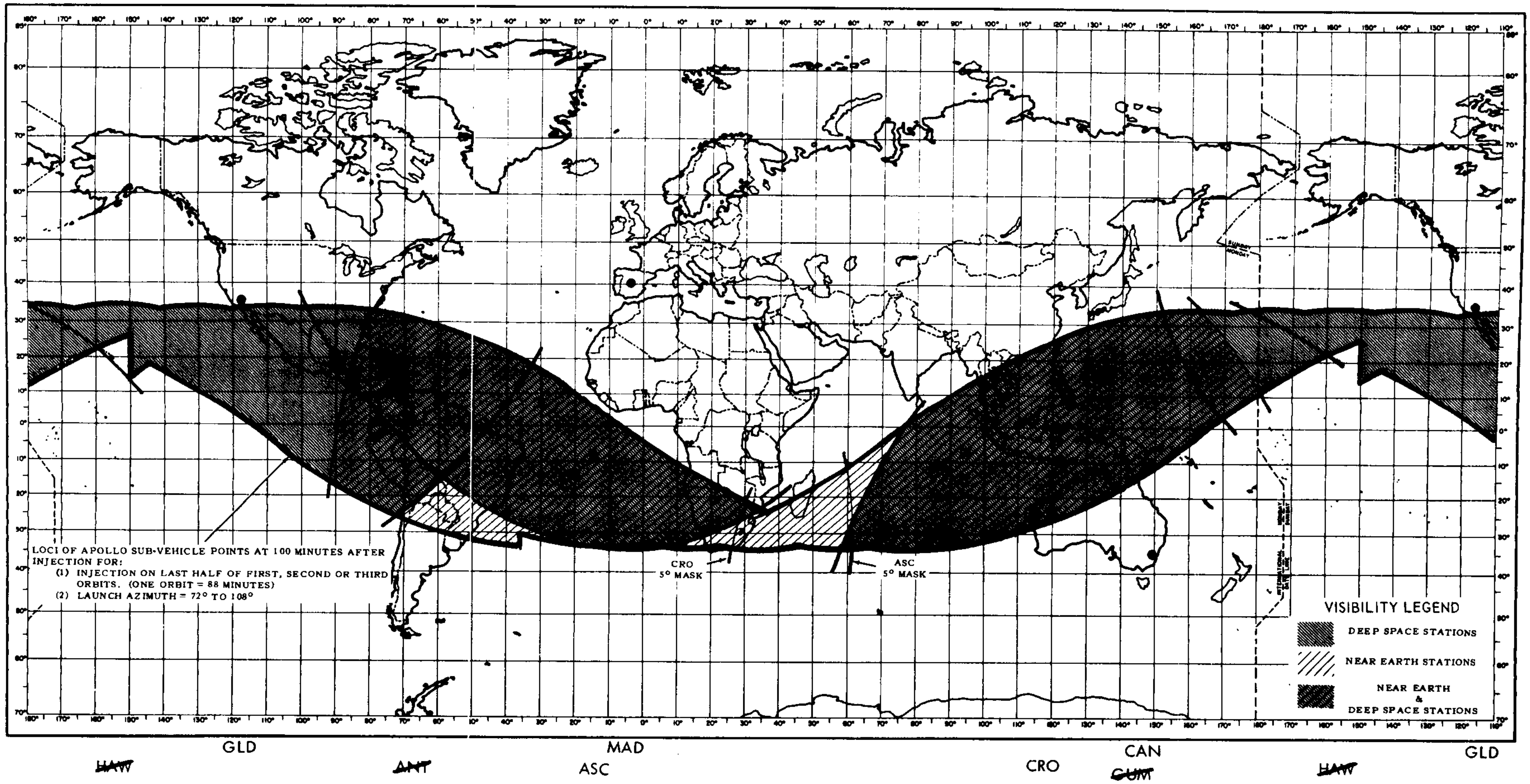
FIGURE 4-4



POST INJECTION VISIBILITY - 60 MINUTES AFTER INJECTION
WITH
THREE DEEP SPACE STATIONS
&
A MINIMUM OF NEAR EARTH STATIONS

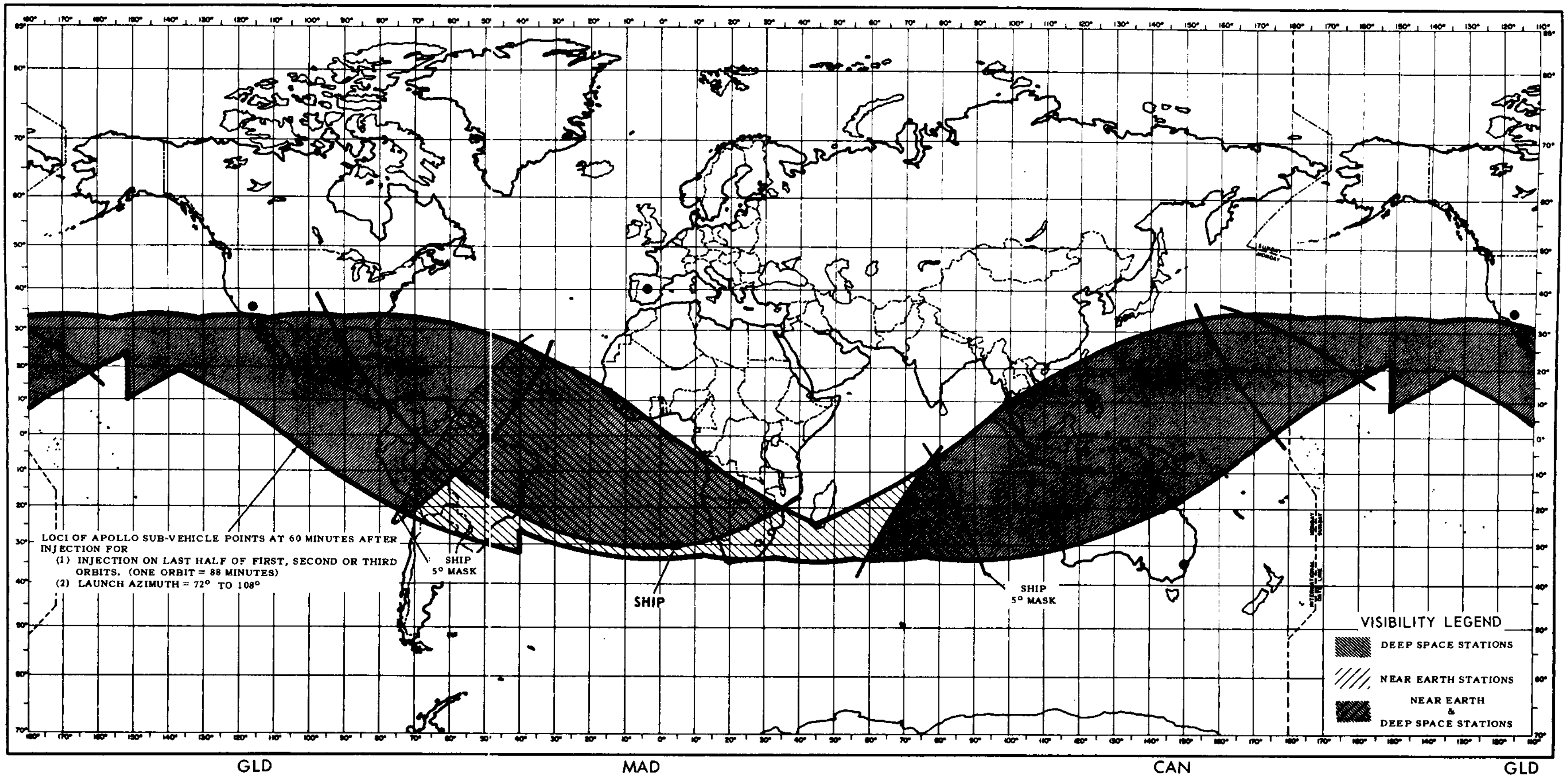
ALTITUDE = 9600 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 12,300 NM

FIGURE 4-5



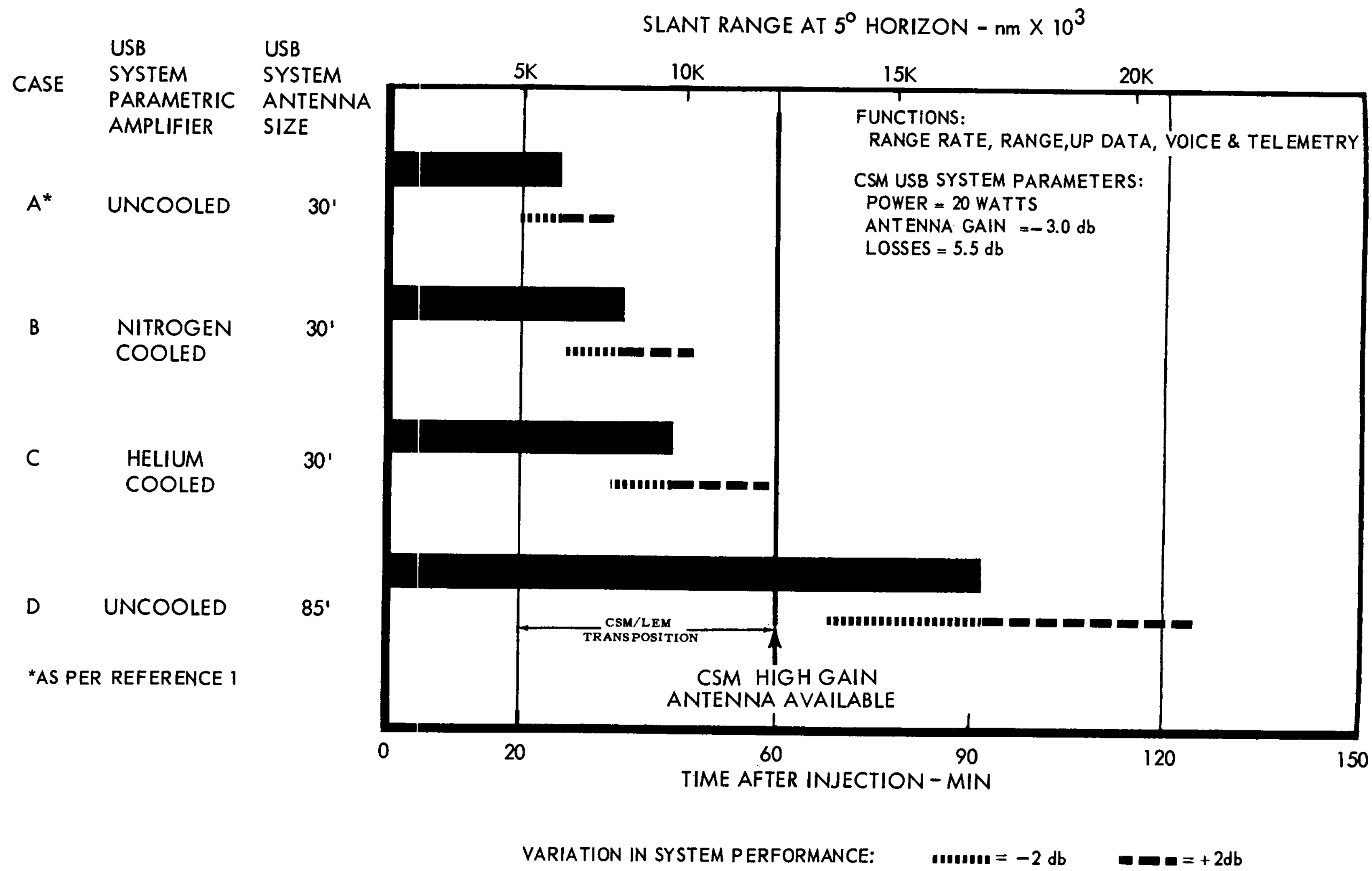
POST INJECTION VISIBILITY - 100 MINUTES AFTER INJECTION
WITH
THREE DEEP SPACE STATIONS
&
A MINIMUM OF NEAR EARTH STATIONS
ALTITUDE = 15,000 NM   ELEVATION = 5° MAXIMUM SLANT RANGE = 17,800 NM

FIGURE 4-6



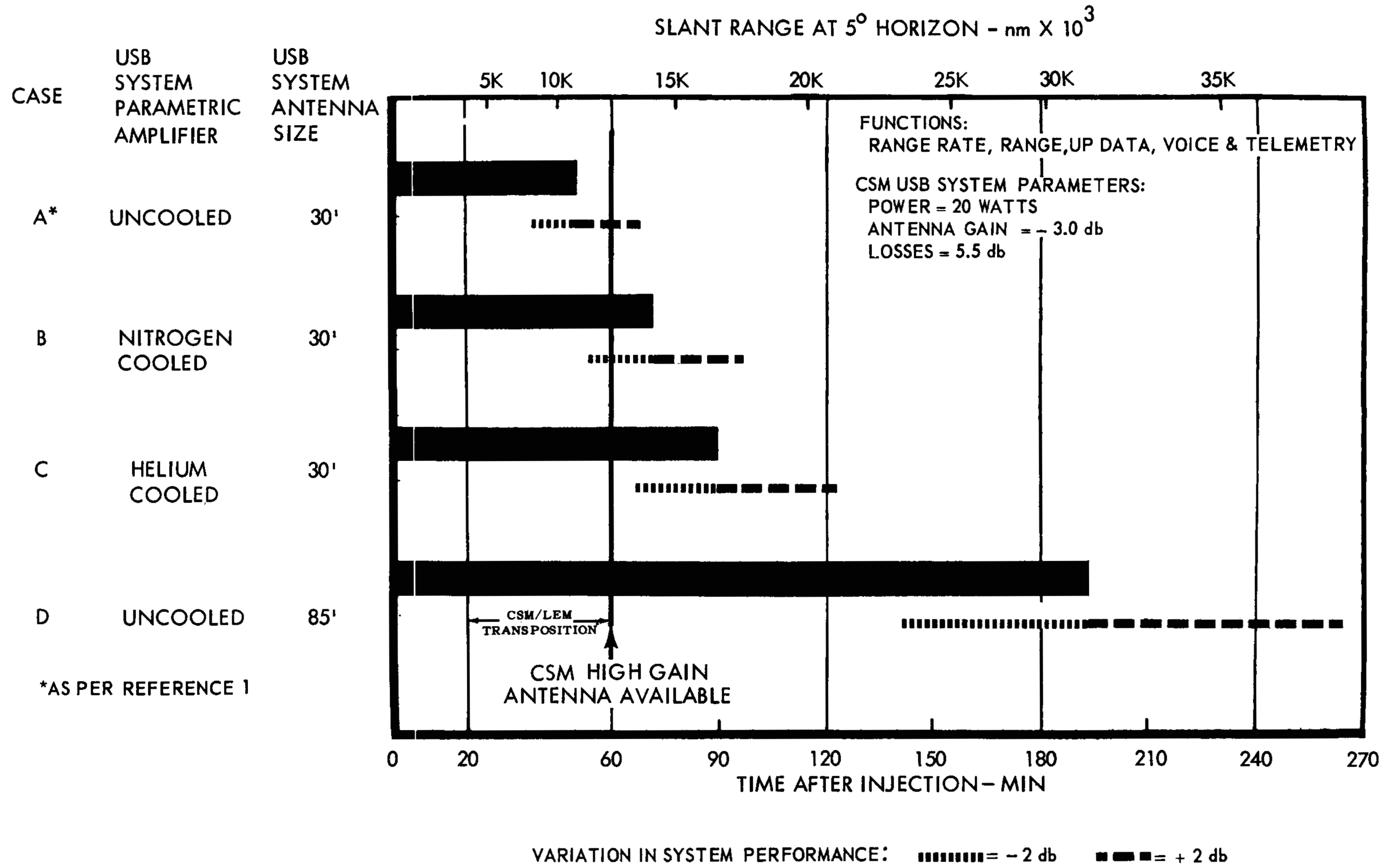
POST INJECTION VISIBILITY - 60 MINUTES AFTER INJECTION
WITH
THREE DEEP SPACE STATIONS
&
APOLLO INJECTION SHIP
ALTITUDE = 9600 NM ELEVATION = 5° MAXIMUM SLANT RANGE = 12,300 NM

FIGURE 4-7



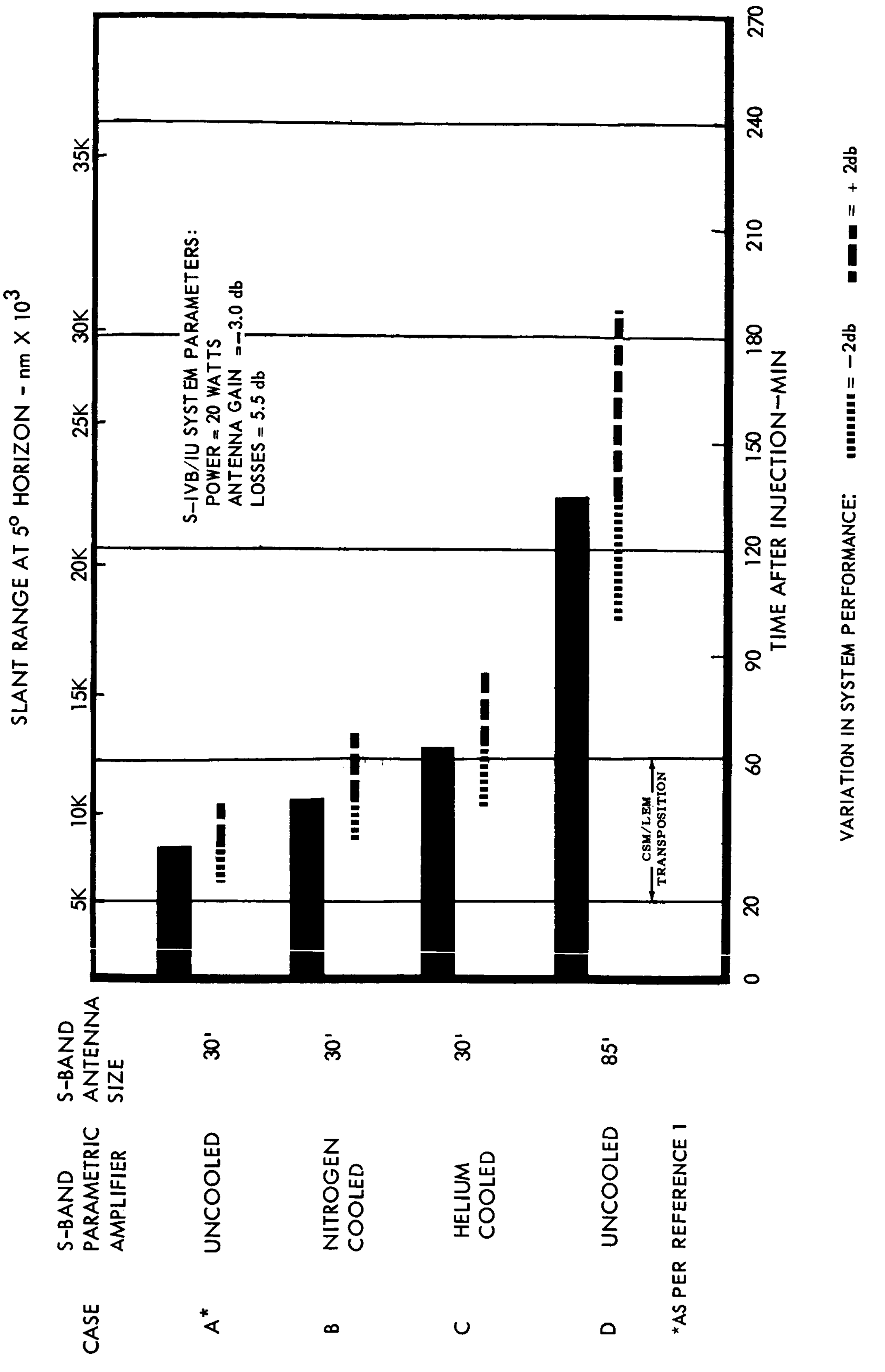
CSM-MSFN UNIFIED S BAND SYSTEM RANGE CAPABILITY - TELEMETRY RATE=51. 2KBS

FIGURE 4-8



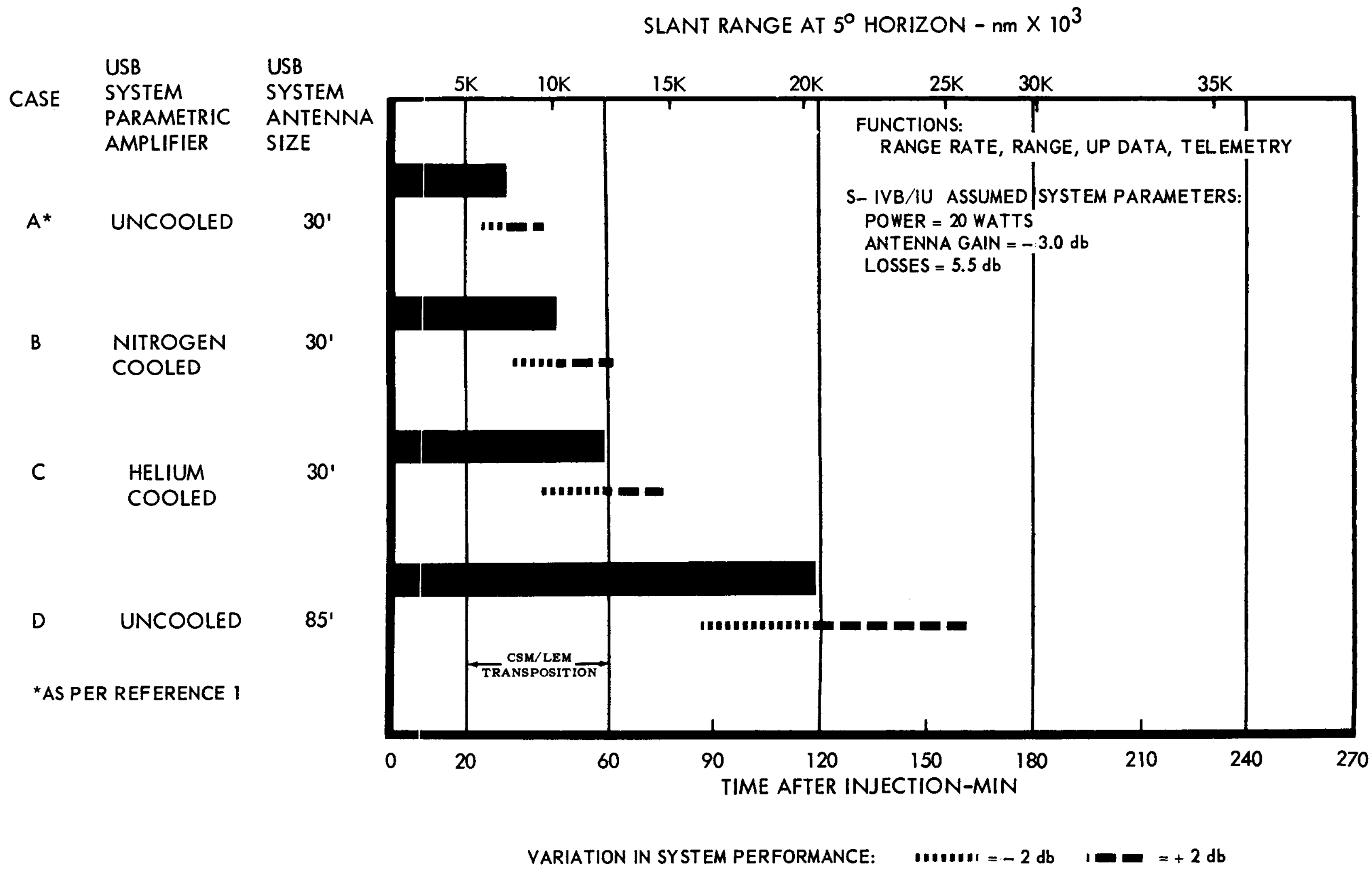
CSM-MSFN UNIFIED S BAND SYSTEM RANGE CAPABILITY - TELEMETRY RATE=1. 6 KBS

FIGURE 4-9



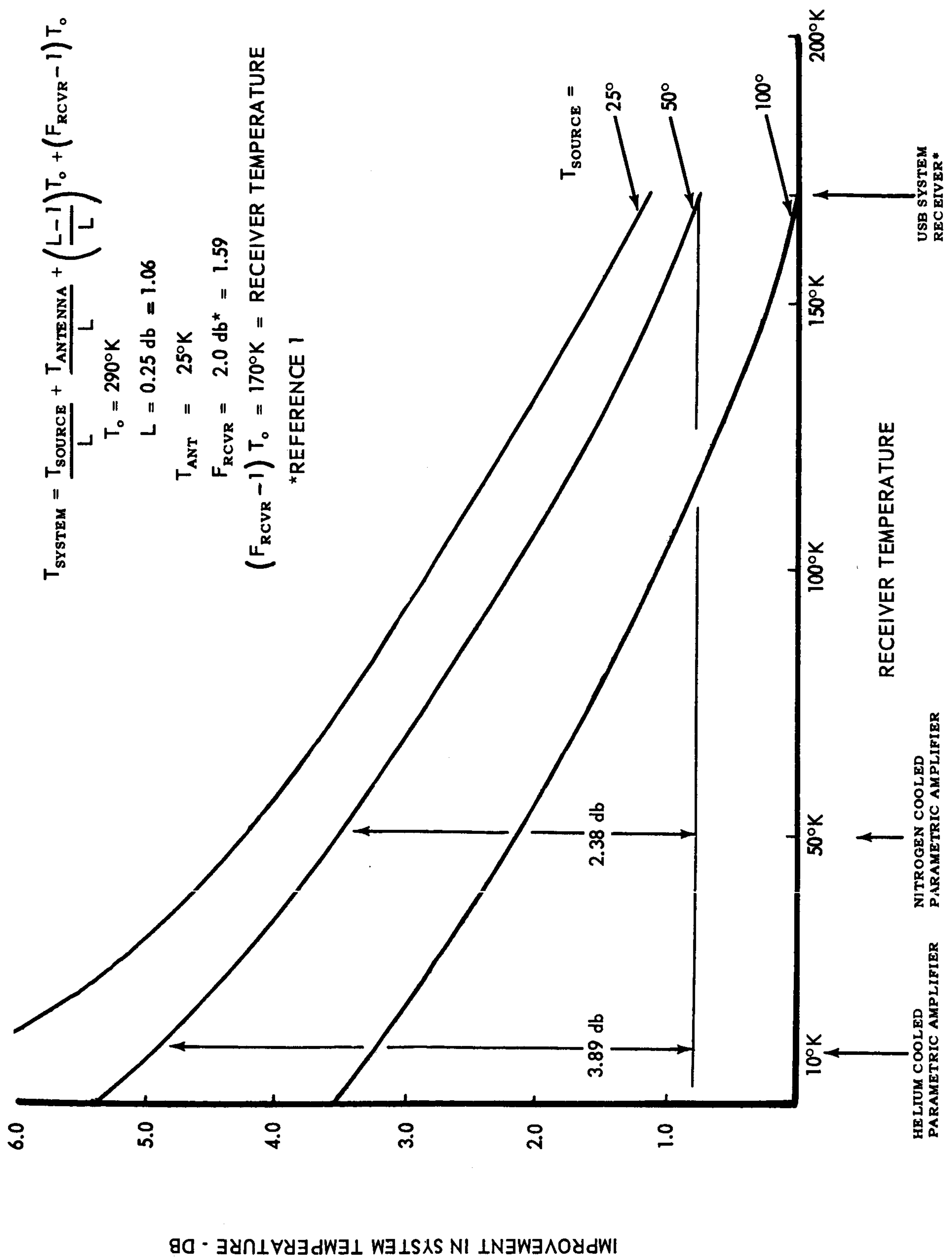
S-IVB/IU-MSFN PCM FM S BAND TELEMETRY SYSTEM RANGE CAPABILITY-RATE =72KBS

FIGURE 4-10



S-IVB/IU-MSFN UNIFIED S BAND SYSTEM RANGE CAPABILITY-TELEMETRY RATE = 72KBS

FIGURE 4-11



EFFECT OF RECEIVER TEMPERATURE ON USB SYSTEM TEMPERATURE

FIGURE 4-12

5.0 Pre-Reentry Phase

The considerations which were applied to post-injection coverage are applicable in establishing communications and tracking coverage for the pre-reentry phase. In this phase, there is a period of time after SM (and high-gain antenna) staging where coverage is dependent upon the CSM omni-antenna. Since the pre-reentry and post-injection altitude profiles are approximately equal, the USB System capabilities shown in Figures 4-8 and 4-9 can be applied to the pre-reentry phase. It is only necessary to read the abscissas as "time before reentry." However, the return to specific landing sites localizes the region of the earth requiring coverage and thereby reduces the number of stations required.

The pre-reentry coverage has been studied in detail in Reference 7 for landings at Samoa and Hawaii, the currently planned water landing locations. It has been found that in addition to Madrid, Canberra and Goldstone, stations at Carnarvon and Guam play an important role in providing the necessary visibility for coverage during this phase. This is illustrated in Table 5-1.

Table 5-1*

Average Pre-Reentry Out of Visibility Time**

Ground Stations	Landing at Hawaii	Landing at Samoa
Madrid, Canberra, Goldstone	67 min.	40 min.
Madrid, Canberra, Goldstone, Carnarvon, Guam	4.4 min.	11 min.

Maximum Ranges Required = 32,000 nm for Carnarvon

= 8,700 nm for Guam

---

*From Reference 7.

**Based on all permissible return trajectories with inclinations less than 40°, reentry ranges between 1200 nm and 5000 nm, and for lunar departure on any day of the lunar month.

Since USB Systems stations with 30 foot antennas are planned for Carnarvon and Guam, realization of the necessary range capability is possible so long as the CSM high-gain antenna is available. There are several situations which would result in dependence upon the CSM omni-antenna during pre-reentry:

a. Partial or total failure of the high-gain antenna,

b. Ineffective operation of the automatic earth seeking function due to the relatively low altitude, and

c. Staging of the SM which contains the high-gain antenna.

Therefore, with high-gain antenna malfunctions, ranges will be limited in the manner shown in Figures 4-8 and 4-9 and discussed in Section 4.0, where Carnarvon or Guam provide the only available visibility.

Staging is now planned to occur late in the pre-reentry phase, i.e., less than about 30 minutes before reentry. Additional studies* of the coverage during this period show that the visibility from sites at Carnarvon, Guam, Madrid, and Canberra is required in this time period. Guam provides single station visibility for a number of return trajectories between 5 and 20 minutes before reentry; Carnarvon provides single station visibility between 5 and 30 minutes. The period from about 20 to 30 minutes before reentry is the maximum communications range with a telemetry rate of 51.2 KBS and 30-foot ground antenna as shown in Figure 4-8. Therefore, a simultaneous requirement for early SM staging (i.e., prior to 30 minutes) and telemetry immediately after staging at 51.2 KBS could not be supported with the planned USB station at Carnarvon. However, early staging and a delayed requirement for telemetry at 51.2 KBS could be supported since late visibility is provided.

A few pre-reentry trajectories which are permissible have incomplete visibility during the last 30 minutes. These can be eliminated with a ship located in the Bay of Bengal as described in Reference 8 and could support the telemetry at 51.2 KBS within the last 20 minutes if equipped with 30-foot USB antennas.

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*See Reference 8.

To summarize, gaps due to range limitations of the USB System do not exist during the pre-reentry phase provided SM staging occurs within the last 30 minutes; if staging occurs earlier, requirements for telemetry at 51.2 KBS would have to be deferred until the last 20 to 30 minutes. A malfunction of the CSM high-gain antenna prior to SM staging would result in range limitation gaps for those return trajectories where Carnarvon provides single station visibility. These could be minimized with an increased range capability at Carnarvon.

6.0 Considerations Concerning Larger Ground Based Antennas

A number of additional factors require consideration if the needed improvement in USB System capability is realized with larger ground based antennas.

The additional range capability at Carnarvon and Ascension can be realized by relocating the MSFN deep-space stations currently planned for collocation with the DSIF deep-space stations at Canberra and Madrid. This would permit a net reduction in total number of USB System facilities required at MSFN stations since the 30-foot USB stations now planned for Carnarvon and Ascension would not be required.

It has been estimated by the Goddard Space Flight Center (GSFC) that relocation of the deep-space station to Carnarvon from Canberra (in place of the planned station) would result in a delay in station completion at Carnarvon of six months to January, 1967. Ascension is not considered to be a desirable site for a deep-space station due to lack of availability of land. The radio frequency interference criteria for deep-space stations may have to be relaxed at both locations, due to lack of natural antenna shielding and relatively high noise levels. Goddard Space Flight Center is currently evaluating these factors for both Carnarvon and Ascension.

Present operational plans indicate that flight control personnel, including medical specialists, will be located at each of the three deep-space stations in sufficient numbers to provide three complete shifts. Any separation of the MSFN and DSIF deep-space stations may require communications circuits of sufficient quality to permit a single group of flight control personnel to utilize either station during a mission. Since communications of this quality are not feasible between Madrid and Ascension or Canberra and Carnarvon, additional operational personnel might be required to supplement those which would be assigned to the Carnarvon or Ascension stations under present plans.

The use of 85-foot antennas at Carnarvon and Ascension assumes the basic capability to acquire and track a spacecraft at the angular rates associated with orbital altitudes of 100 nautical miles. It is understood that the GSFC 85-foot X-Y antenna mounts at Rossman, N.C., and Fairbanks, Alaska are similar to the planned deep-space antennas. They are designed to support satellites with a minimum altitude of 80 miles and this capability has been demonstrated. The acquisition procedure associated with the USB System is not clearly defined at this time for 30-foot antennas. Therefore, it is difficult to assess the acquisition penalty, if any, associated with the use of larger antennas for orbital support. Such assessment would be required if larger antennas are to be used for orbital support.

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